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Team training: role of computers in the aircraft maintenance environment

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Abstract

Research on civil aircraft inspection and maintenance has shown the importance of teamwork in the aircraft maintenance environment. In addition, training has been identified as one of the primary intervention strategies in improving team performance. With improvements in technology-based training devices, it may be possible to provide aircraft maintenance technicians with training tools to help enhance their team skills and improve performance with the aircraft maintenance environment. This research examines the effectiveness and applicability of computer-based multimedia team training for aircraft maintenance technicians. Using a computer-based multimedia training tool—the Aircraft Maintenance Team Training (AMTT) software—a controlled study was conducted to: (1) evaluate the use of computers in acquiring knowledge on team skills, (2) determine the ease of use of a computer-based multimedia tool, and (3) determine if computer-based training was as effective as traditional instructor-based training. The results are reported as part of this paper.

1. Introduction

To provide the public with a continuing safe, reliable air transportation system, it is important to have a sound aircraft maintenance system [8]. The maintenance system is a complex one with many interrelated human and machine components. The linchpin of this system, however, is the human. Recognizing this, the FAA (under the auspices of the National Plan for Aviation Human Factors) has pursued human factors research [8,9]. In the maintenance arena, this research has focused on the aircraft maintenance technician (AMT) [7,27–29]. Since it is difficult to eliminate errors altogether, continuing emphasis must be placed

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on developing interventions to make the maintenance procedures more reliable and/or error tolerant.

Task analyses of aircraft inspection activities have revealed that the aircraft inspection and maintenance system to be complex necessitating above average coordination and communication between various work groups (e.g. aircraft maintenance technicians, planners, cleanup crews, stores and shops) [7,8,10,31]. A large portion of inspector and maintenance technician work is accomplished through teamwork. The challenge is to work autonomously but still be a part of the team. In a typical maintenance environment, first, the inspectors look for defects and report them. The maintenance personnel then repair the reported defects and work with the original inspector or the buy-back inspector to ensure that the job meets predefined standards. During the entire process, the inspectors and maintenance technicians work with their colleagues from the same shift and the subsequent shift as well as personnel from planning, stores, etc. as part of a larger team to ensure that the task gets completed [8]. Thus in a typical maintenance environment, the technician has to learn to be a team member, communicating and coordinating the activities with other technicians and inspectors. Although the advantages of teamwork are widely recognized in the airline industry [13], the work culture assigns responsibility for faulty work on individual AMTs rather than to the teams on which they work. The reasons for this could be the individual licensing process and personal liability, both of which often results in AMTs and their supervisors being less willing to share their knowledge and work across shifts with less experienced or less skilled colleagues. The problem is further compounded since the more experienced inspectors and mechanics are retiring and being replaced by a much younger and less experienced workforce. Not only do the new AMTs lack knowledge or skills of the far more experienced AMTs they are replacing, but also they are not trained to work as team members.

AMTs joining today's workforce, however, are lacking in team skills. The Aircraft Maintenance Technology Schools (AMTS) provide the necessary technical skills for students to receive both their airframe and power plant certificates (A&P license), but the AMTs are often ill-prepared for cooperative work. To prepare student AMTs for the workplace, new ways have to be found to build students' technological, interpersonal and socio-technical competence by incorporating team training and communication skills into their curriculum. Moreover, the importance of teams has also been emphasized in the National Plan for Aviation in Human Factors [8,9,27,29] where both the aircraft industry and government groups agreed that additional research needs to be conducted to evaluate teamwork in the aircraft maintenance/ inspection environment. The question that begs to be answered is: What is the best method to present team skills training?

With computer-based technology becoming cheaper, the future will bring an increased application of advanced technology to training. Over the past decade, instructional technologists have provided numerous technology-based training devices with the promise of improved efficiency and effectiveness. Examples of such technology include computer simulation, interactive video discs and other derivatives of computer based application. Several of these have been employed for diagnostic maintenance training [16,17,27,29]. Furthermore, multimedia has assisted in teaching difficult and complex skills [11]. Layton [19] stated that the domain of aircraft maintenance is rapidly becoming the focus of computer-based training (CBT) aids. With the use of desktop computers with multimedia packages, new maintenance job aids have been developed to teach technical skills to maintenance technicians. AMTs may learn a variety of skills from CBT that range from scheduling preventive maintenance to applying expert systems for fault diagnosis and repair. Lufthansa Airlines believes so strongly in CBT that they have instituted CBT with video overlays to update the technical skills of their maintenance technicians [23]. Andrews et al. [1], also described various multimedia technologies that have been effective in simulating combat situations for team training in the military. Because of the advantages offered, computer-based training may have a role to play in team training in the aircraft maintenance environment. It is important, therefore, to examine the effectiveness and applicability of computer-based multimedia team training for aircraft maintenance technicians.

The general objective of this study was to demonstrate the effectiveness of advanced technology for team training. To facilitate the study, a computer-based multimedia training tool — the Aircraft Maintenance Team Training (AMTT) software — was developed. AMTT provided the AMTs instruction on team skills which are necessary to function cooperatively and effectively in the aircraft maintenance environment. The specific objectives of this research

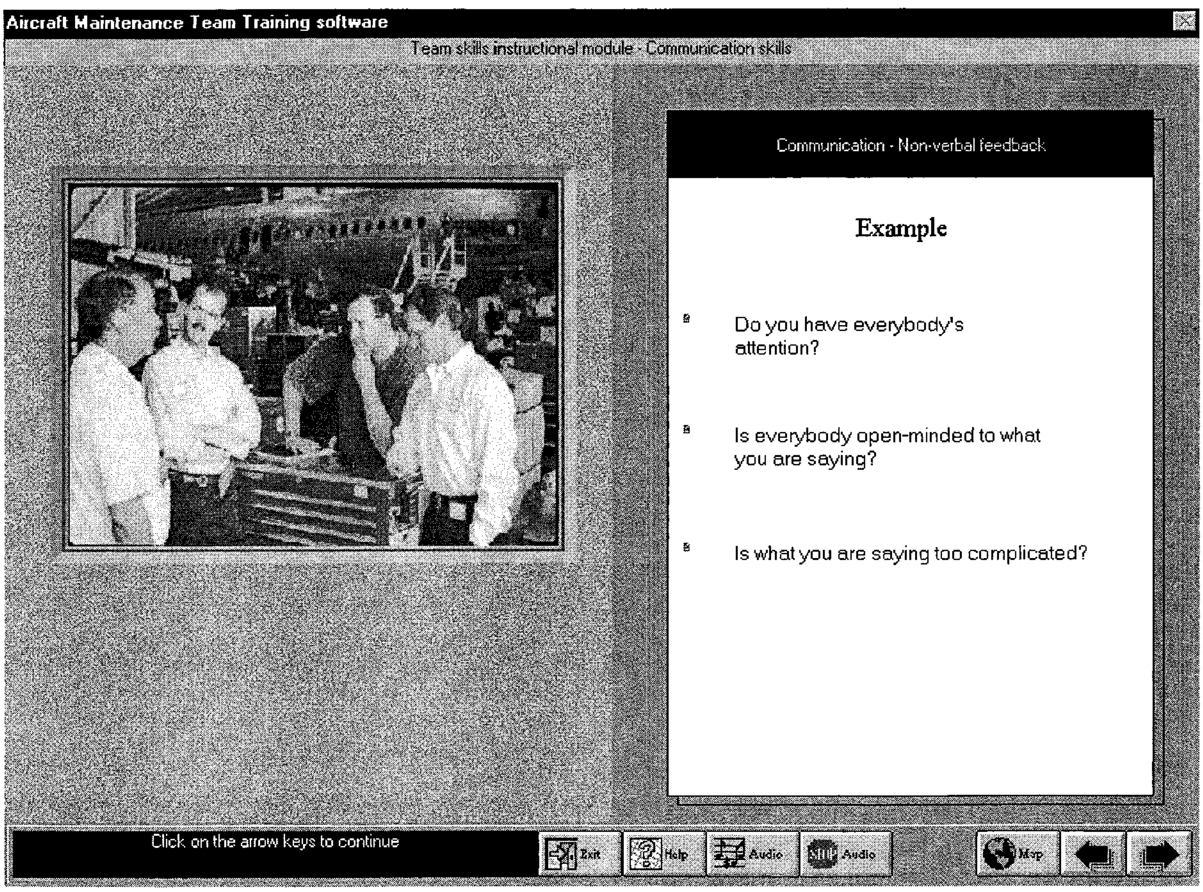

Fig. 1. Prototypical layout of team skills module.

were: (1) to evaluate the usefulness of computers in assisting AMTs in acquiring knowledge on team skills, (2) to determine if a computer-based multimedia tool would be easy for AMTs to use and (3) to determine if computer-based team training was as effective as traditional instructor-based training. Initially, this paper describes the computer-based multimedia team training software (AMTT). Ultimately, the results of an experimental study conducted to determine the effectiveness of computers in delivering team skills instruction are reported.

2. Computer-based team training: aircraft maintenance team training (AMTT) software

Specifically designed for training aircraft maintenance technicians in basic team skills, AMTT uses a multimedia presentational approach with interaction opportunities between the user and the computer. The multimedia presentation includes: full motion video which provide

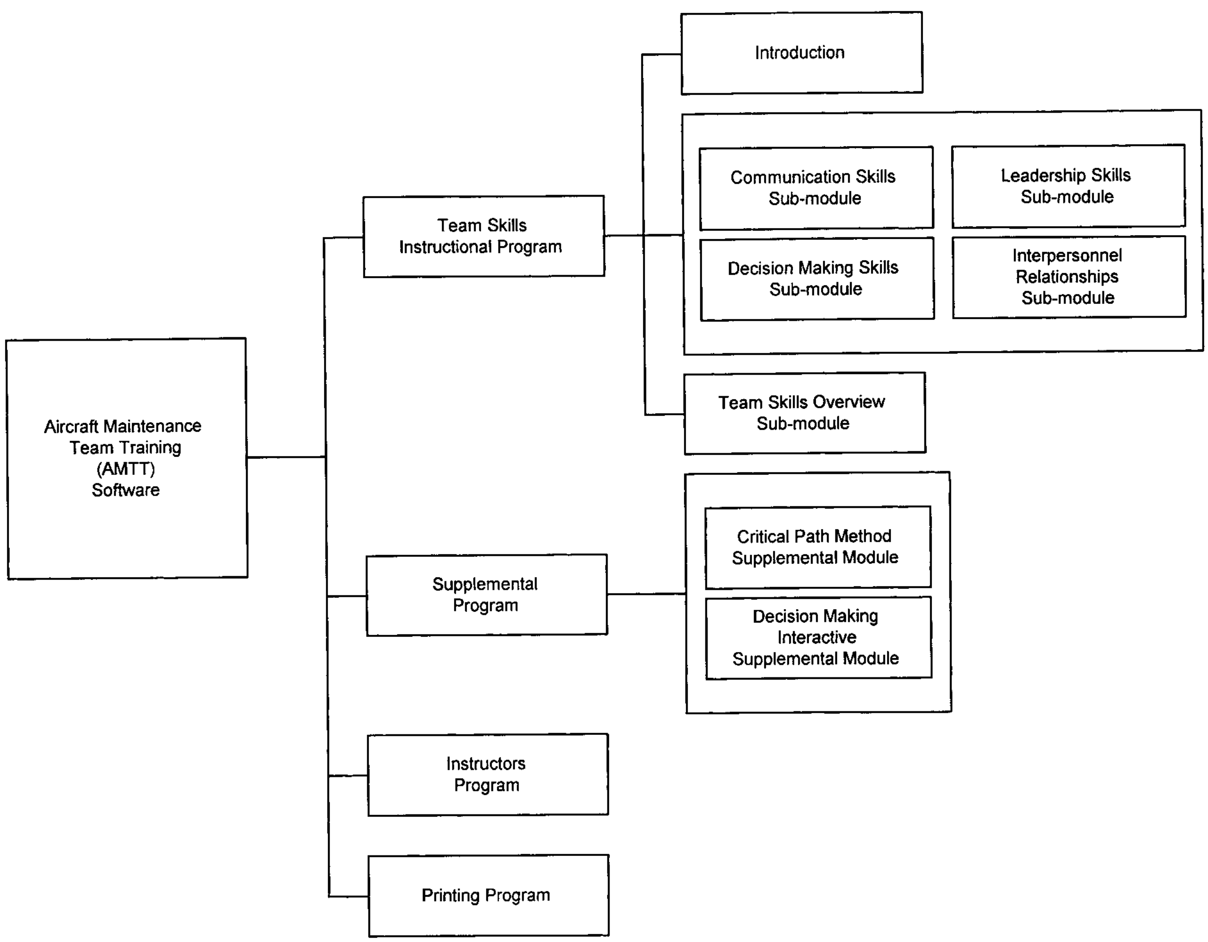

Fig. 2. Layout of the aircraft maintenance team training (AMTT) software.

real life examples of proper and improper team behavior, photographs and animation that illustrate difficult concepts and voice recordings coupled with visual presentations of the main contextual material. Since the software was developed as a training and research tool, the software facilitates the collection of pretraining and posttraining performance data.

Figure 1 shows a prototypical layout of the team skills module. The right side of the screen is dedicated to key points being discussed in the voice-over, while the left side of the screen provides supporting material. This supporting material comes in a variety of formats which include, but are not limited to, animation, video, photographs, diagrams and flow charts. Buttons on the command line at the bottom of the screen can be clicked on to exit, advance, back-up, stop and replay audio, replay video and access the navigational map. On-line help is also available and is structured similar to Microsoft Help. Each of the team skill submodules has a similar structure. The submodules start with a short test that is intended to measure the trainees' current knowledge of the subject matter. On completion of the test, the user is presented with the instructional material. The tutorial material is broken down by major topics. After each topic, a test is presented before proceeding to the next topic. These embedded tests serve two purposes: first, they verify that the user has understood the material just presented. Second, it serves to reinforce the knowledge the user acquired. The test questions are repeated at the end to measure the change, if any, in the subject's understanding of a specific team skill.

2.1. Specifications

AMTT was developed in Microsoft Visual Basic and runs on the Microsoft Windows environment. AMTT uses the 486 DX2 66 MHz platform, with a 15 inch SVGA monitor, 16 MB RAM, 2 MB video RAM, MCI compatible sound card and a multispeed CD.

2.2. Layout

AMTT is divided into four major programs (see Fig. 2): (1) Team Skills Instructional program, (2) Instructor's program, (3) Printing program and (4) the Supplemental program. While the Team Skills Program and the Supplemental Program have been designed for use by the aircraft maintenance technician undergoing team training, the remaining two programs are for use by the instructor/supervisor. An aircraft maintenance technician (AMT), interacting with the AMTT software, first uses the Team Skills Instructional program which initially provides an introduction to the software. Following this step, the AMT is provided with instruction on basic team skills through four separate team skill submodules — communication, leadership, decision making and interpersonal relationships. These submodules not only emphasize and cover generic material related to these skills but also relate the importance and use of the specific skills within the aircraft maintenance environment. These are the same four skills which have been emphasized in an earlier FAA [10] report which looked at the role of team training in the aircraft maintenance environment. The following sections discuss each submodule in greater detail.

2.2.1. Communication submodule

Communication between team members is critical for the successful completion of team tasks [25]. Working with instructors from the Guided Missile School in Norfolk, VA., Hogan et al. [14] found that the most frequent cause of poor team performance was improper team member communication. To prevent this problem, Hogan et al. [14] recommend the use of a low fidelity computer-based training program to teach communication skills. Shepherd [27,29] explains the importance of communication in the aircraft maintenance environment where technicians must be able to communicate effectively in written and spoken discourse. Addressing these needs, this Communication submodule was divided into six major topic areas.

The first topic examines the different methods of communication in the aircraft maintenance environment. Verbal and nonverbal forms of communication are discussed and examples are provided which illustrate how individuals communicate through posture, expressions and actions. The communication process is covered as the second topic. Then, in the following section, those parts of the communication process that are likely to create communication problems in the aircraft maintenance environment are addressed. Fourthly, the importance of feedback on performance is covered and the proper way to give and receive feedback is presented. Also addressed within the topic of feedback is the concept of active listening. The fifth topic is written communication which in the aircraft maintenance industry comes to the aircraft technician in many forms. The most critical aspect for the technician is the routine and nonroutine work cards. The user is introduced to the importance of these work cards and through the use of examples learns how to identify the typical errors made in completing one. The final topic of this submodule deals with the proper and improper procedures for a shift change. According to Shepherd [26], contrary to the dictates of the organization, very little, if any, communication takes place during a shift change. Yet, this is the one critical time when all the various forms of communication come into play — verbal and nonverbal communication, feedback and active listening and written communication. Through the use of videos, the user sees and hears the incorrect and then the correct procedures for a shift change.

2.2.2. Decision making submodule

Decision making has been identified as an important teamwork skill dimension [3]. In a team environment, team members must have the ability to gather and integrate information for problem assessment, to generate alternative solutions, to prioritize solutions and make decisions and to implement their decisions [25]. Furthermore, the team members need to be aware of specific strategies and tools that can be used in situations when uncertainty or disagreement exists about the nature of a problem and possible solutions [22]. The objective of this submodule was to explain the importance of a well-defined decision-making procedure, to introduce the user to a variety of decision making tools and to train the user on the proper use of these tools. The decision making submodule has three main topic areas. The first three topics — problem identification, generation of ideas and decision making tools — follow the main steps in the decision making process. Later a detailed description of the three decision making tools (Consensus, Multivoting and Nominal Group Technique) is presented. Using animation, the user is introduced to the basics on how and when to use the three decision making tools. As part of a separate interactive decision making exercise (Interactive Decision

Making supplemental module) the user applies the different tools to resolve a real life aircraft maintenance problem.

2.2.3. Interpersonal relationships submodule

The importance of interpersonal relationships as a team skill has been recognized by a number of authors (e.g. [3,15,25]). Coovert and McNelis [6] state that interpersonal skills is one of the major factors that affect decision making in a team and McCallum et al. [20] found a positive relationship between supportive behavior and team performance. The purpose in providing training to the user in interpersonal relationship skills is to help them to become more knowledgeable about the effects of various individual behaviors on team performance, to recognize specific behavioral problems that may occur in a team environment and to deal with those behavioral problems in an effective and constructive manner. The interpersonal relationships submodule includes a discussion on the various stages of a team's growth, the characteristics of successful teams and the use of ground rules in a team environment. In the final section of this submodule, typical personality and behavioral problems that a user may encounter are presented in an aircraft maintenance situation context. The user learns to identify the problems and to respond with appropriate solutions.

2.2.4. Leadership submodule

According to McIntyre et al. [21], proper team leadership has a positive effect on team performance. Burgess et al. [2] state that the performance of a team is often a direct reflection of ability and performance of the team leader. Swezey and Salas [30] extracted a number of guidelines for effective team leadership from the literature on teams and teamwork, which were used in developing the leadership submodule. The leadership submodule not only helps to summarize the previously discussed team skills, but also reviews additional skills that are necessary for both the lead mechanics (supervisors) and the aircraft maintenance technicians. The first topic is covered in this submodule is the role of the team leader. Team leaders and team members must know and understand the importance of their roles within the team and within the organization. In addition, they must recognize various leadership styles and be able to use coaching and counseling techniques in directing their teams. The next three topics in this submodule consist of a review of communication, decision making and interpersonal relationship skills within the context of leadership and with additional concepts that are germane to proper leadership. The final two topics, which have not previously been covered, include training and coordination. Under the training topic, the need to be proactive rather than reactive is stressed. Leaders (lead mechanics and supervisors) need to be mindful of on-the-job training opportunities and they must be concerned with the constant upgrading of their team members' skills through off-line training. The final topic addresses coordination. Many authors treat coordination as a separate team skill (e.g. [3,30]). For the purposes of this tutorial, however, coordination was included as a part of leadership, because a team leader has the responsibility to coordinate activities and resources both at the team level and at the organization level. Since the leadership submodule addresses both the general team members as well as team leaders, the training information on coordination is available to all tutorial users. Both internal and external coordination are described and the importance of good coordination skills is highlighted.

2.2.5. Other programs and modules

After completion of the team skills modules, the information is summarized in the team skills overview module. In addition to the four basic team skill modules, AMTT also provides the AMT with a supplemental program. The supplemental program consists of two separate supplemental modules — the critical path method and interactive decision making. The objective of the supplemental modules is to provide users with hands-on experience in the use of the specific decision making tools in a simulated team environment. It is anticipated that this interactive experience will enhance learning and the use of the above-mentioned tools in the real world environment. Since the software was developed as both a training and research tool, the software facilitates the collection of pretraining and posttraining performance data. The instructor can access and analyze user performance data using the instructor's program. The printing program is an additional utility provided to the instructor to print the various screens in each of the team skills modules and present the information in an alternate instructional format.

3. Methodology

A controlled study was conducted to evaluate the effectiveness of advanced technology for team training. The following section describes the test site, participants, equipment and experimental procedures used in this study.

3.1. Test site

The controlled study was conducted at the Aircraft Maintenance Technology Center of Greenville Technical College (GTC). The center houses both classrooms for Airframe and Powerplant (A&P) training and a fully equipped hanger for conducting aircraft maintenance repairs. The classrooms at the Aircraft Maintenance Technology Center provide seating for 20 students. Each classroom is equipped with a 25-inch color television, video player, overhead projector, white and black boards and a lectern. In addition, the classrooms are equipped with four Pentium 75 MHz computers and 15-inch color monitors (1024 × 768 resolution) installed with multimedia packages.

3.2. Test subjects

The subjects for this research consisted of 12 students from the Aircraft Maintenance Technology Center and 24 licensed A&P mechanics from a local aircraft maintenance facility (Lockheed Martin Aircraft Center). The subjects were compensated for their participation.

The 36 subjects were assigned to two groups such that each group had equal number of subjects from Greenville Technical College and the maintenance facility.

Group IBT, instructor-based training: received team training instruction through tradition instructor-based training (IBT).

Group CBT, computer-based training: received team training instruction through multimedia computer-based training (CBT) (the AMTT software).

3.3. Equipment

Table 1 provides a list of the equipment used in the controlled study. To keep the two training delivery systems as similar as possible, the video clips used in the IBT were identical to the video clips used in the CBT. In addition, the transparencies used in the IBT were screen captures from the screen images presented in the CBT.

3.4. Data collection

Subjects in the IBT group were trained on team concepts using a traditional instructor-based training delivery system, while those in the CBT group received similar training on a computer using the AMTT software. Every effort was made to maintain a constant curriculum and presentation sequence for both groups. The only difference in the training between the two groups was the type of delivery system. The team skills training focused on the following four separate skills: communication, decision making, interpersonal relationships and leadership. More details on the structure and content of the team training program can be found in Kraus [18].

Prior to participating in this research, each subject was required to read and sign a consent form. A special effort was made to assure the subjects that their performance in this experiment would have no effect on their school grades or performance evaluation at work.

Before and after each team skill submodule, each subject was administered a 20-question multiple choice test. This test was designed to measure the change in knowledge on the specific team skill. At the conclusion of training, each subject completed two sets of usability questionnaires. The questionnaires collected subjective satisfaction ratings on the training delivery system using a seven-point Likert scale, where seven indicated strongly agree and one indicated strongly disagree. The first questionnaire (General Questionnaire) contained

Table 1
Equipment used throughout controlled study

Training delivery system	Equipment
Instructor-based training (IBT)	overhead projector with transparencies television with video player white board lectern video miscellaneous paper and pencils
Computer-based training (CBT)	four Pentium 75 MHz computers with full multimedia package Aircraft Maintenance Team Training (AMTT) software

questions relevant to both the training delivery systems and was completed by subjects in both the groups. The General Questionnaire addressed usability issues related to: content, mechanics of presentation, format and usefulness. The second part of the usability questionnaire was training delivery system specific and addressed the usability issues — presentation and format.

3.5. Knowledge test analysis

The objective of this analysis was to understand the effect of team training on the subject's knowledge of team skills. The knowledge test analysis used a 2 (method of training delivery: CBT, IBT) $\times$ 2 (trials: pretraining, posttraining) design with 18 subjects nested within each group. The method of training delivery was the between subjects factor and the trials was the within subjects factor.

3.6. Usability analysis

Usability scores between the two groups were analyzed in two separate ways. Scores on the General Questionnaire were analyzed using an ANOVA for each usability category (contents, mechanics, format and presentation). Similarly, consolidated scores obtained after adding the scores for each usability category were analyzed using an ANOVA. The delivery specific portion of the questionnaire was analyzed using a t-test. A two-tailed t-test was used to compare actual means with expected means on delivery system specific usability issues (presentation and format).

4. Results

This section presents the results obtained from the instructional and evaluation phases of the study. Statistical Analysis Software [24] was used to analyze the data obtained for the different measures.

4.1. Effects on team skills knowledge

To measure the effects of team training on a subject's knowledge of team skills, all the subjects were administered a multiple choice test on the various team skills (communication, decision making, interpersonal relationships and leadership) before and after training. The multiple choice test was divided into four sections (one for each skill category), with 20 questions on each skill category. The maximum score an individual could obtain in the pre and posttest for each skill category was 20. ANOVAs conducted on the pre and postteam skills knowledge scores showed a significant Trial effect for communication ($F(1, 34) = 9.37$, $p < 0.001$), decision making ($F(1, 34) = 112.10$, $p < 0.001$), interpersonal relationships ($F(1, 34) = 42.1$, $p < 0.001$) and leadership ($F(1, 34) = 14.36$, $p < 0.001$). The Group $\times$ Trial interaction effect and the main effect of Group were not significant.

Table 2
Usability questionnaire, general questions for groups IBT and CBT

Statements	Group IBT mean (SD)	Group CBT mean (SD)
C1: The amount of information presented was adequate	5.22 (1.36)	5.61 (0.98)
C2: The subjects were thoroughly covered	6.06 (0.85)	5.72 (1.07)
C3: The information presented was understandable	6.06 (0.91)	6.22 (0.73)
M1: The videos were helpful in understanding the concepts presented	6.06 (0.85)	6.00 (0.97)
M2: The short questions presented during instruction were helpful in reinforcing what you learned	5.94 (1.08)	5.89 (1.41)
M3: The language used by the speaker was understandable	6.5 (0.69)	6.39 (0.70)
F1: The screens/overheads were understandable	5.39 (1.42)	5.89 (1.02)
F2: The information presented flowed smoothly	5.78 (1.18)	5.33 (1.08)
F3: The presentation was interesting	5.89 (1.24)	5.72 (0.96)
U1: The knowledge gained from each of the following modules was useful:		
(a) communication	6.11 (0.87)	5.83 (0.92)
(b) decision making	6.22 (0.85)	5.50 (1.47)
(c) interpersonal relationships	6.06 (1.08)	5.89 (0.90)
(d) leadership	6.17 (0.76)	5.83 (0.99)

4.2. Usability

As previously mentioned, at the conclusion of the team skills training, all subjects completed a two-part questionnaire that addressed the usability issues related to the team training program. All questions were based on a Likert scale with a range of 1–7. The first part of the questionnaire asked general questions that were applicable to both the delivery systems. The second part of the questionnaire contained questions specific to the training delivery system (instructor-based training (IBT) and computer-based training (CBT)). The following sections describe the results for each of the usability questionnaires.

4.2.1. General usability

Subjects in both groups responded to 13 general questions concerning the usability of the training delivery system. The questions along with the mean score and standard deviation are reported in Table 2. These questions were consolidated into four major categories:

1. Content (questions C1, C2 and C3).
2. Mechanics (questions M1, M2 and M3).
3. Format (questions F1, F2 and F3).
4. Usefulness (questions U1a, b, c and d).

Separate scores were obtained for each usability category after ensuring that it was appropriate to group the responses into an aggregate measure (Cronbach, 1951), then separate ANOVAs were conducted on the aggregated measures for each usability category. In addition, ANOVA was conducted on the combined scores (obtained after aggregating individual scores on each usability category). Individual ANOVAs did not reveal any significant between Group effect for any of the usability categories. As expected, the combined ANOVA also did not show any significant between Group effect.

4.2.2. Usability of instructor-based training delivery system

Questions on the delivery system specific (IBT) portion of the questionnaire were consolidated into two major categories: presentation (questions P1, P2 and P3) and format

Table 3
Usability questionnaire, instructor-based training

Statements	Mean (SD)
P1: The instructor was effective in presenting the material	6.17 (0.71)
P2: The presentation was interesting	5.89 (1.41)
P3: The instructor talked at an acceptable pace	5.67 (1.37)
F1: The videos were easy to see	5.94 (1.47)
F2: The overhead projections were easy to see	5.22 (1.35)
F3: The instructor interacted well with the students	6.61 (0.50)
F4: The instructor was easy to understand	6.44 (0.86)
F5: I was satisfied with the effectiveness of this classroom training	6.33 (0.69)

Table 4
Usability questionnaire, computer-based training

Statements	Mean (SD)
P1: The voice over helped in understanding the material	6.00 (1.03)
P2: The tutorial was easy to use	6.22 (0.88)
P3: It was easy to navigate through the tutorial	6.11 (0.96)
F1: The colors used on the screen were pleasing	5.94 (1.00)
F2: The buttons on the screen were easy to understand	6.22 (0.88)
F3: The delays while the computer worked did not frustrate you	4.67 (1.81)
F4: You were satisfied with the interaction with the computer	5.72 (0.96)
F5: The tutorial was effective in providing instruction	5.94 (0.87)

(questions F4, F5, F6, F7 and F8). Table 3 gives the list of IBT usability questions showing the mean scores and standard deviation on each question for both the Groups. As with the general usability categories, scores for the training specific categories were grouped after ensuring that it was appropriate to group responses into an aggregate measure.

A two-tailed t-test was used to compare the actual mean scores versus expected mean score for both the usability categories and the questionnaire as a whole. The null hypothesis stated that the actual mean score was equal to 3.5 and the alternate hypothesis was that the mean score was not equal to 3.5 (H_0: $\mu = 3.5$ and H_a: $\mu \neq 3.5$). The t-test rejected the null hypothesis for presentation category ($T_0 = 12.16$, $p < 0.05$), format category ($T_0 = 17.02$, $p < 0.05$) and the questionnaire as a whole ($T_0 = 16.5$, $p < 0.05$).

4.2.3. Usability of computer-based training delivery system

As with the instructor-based training, the subjects receiving computer-based training (CBT) were also given a separate usability questionnaire wherein the questions were categorized into two categories: presentation (questions P1, P2 and P3) and format (questions F4, F5, F6, F7 and F8). The list of the CBT questions with the average score and standard deviation for each question is provided in Table 4.

As with the IBT, a two-tailed t-test was used to compare the expected average value of the subject's ranking on usability to the actual mean value. The t-test rejected the null hypothesis for presentation ($T_0 = 12.47$, $p < 0.05$), format ($T_0 = 11.38$, $p < 0.05$) and the questionnaire as a whole ($T_0 = 12.94$, $p < 0.05$).

5. Discussion

5.1. Changes in knowledge test scores

A comparison of the pre- and posttraining knowledge test is shown in Fig. 3. In every skill category there was a significant increase in the test scores after training. The fact that both

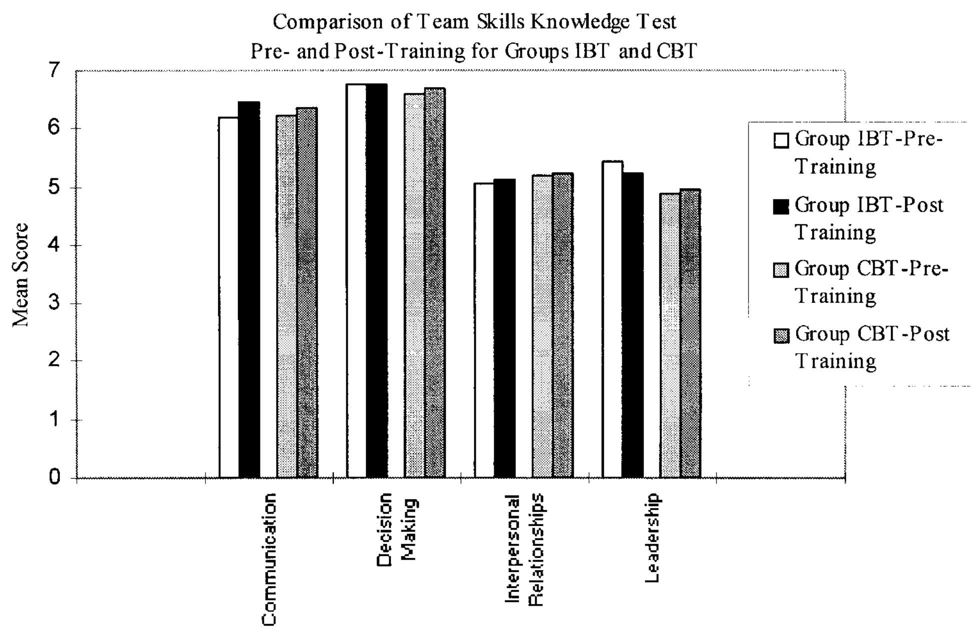

Fig. 3. Comparison of team skills knowledge test pre and posttraining for groups IBT and CBT.

training programs showed comparable increases in test scores probably indicates the effectiveness of both methods of delivering team training. These results are encouraging in regards to the potential of the team training program in imparting team skills knowledge. The results are consistent with other researchers who have found similar results in improving team skills by training. Taylor et al. (1993) conducted a crew resource management (CRM) training program for aircraft maintenance personnel and found that maintenance performance measures increased after training. Also, in a study to improve team work in engineering design education, Ivaturi et al. [15] found that team training instruction enhances a student's knowledge of team skills.

It is interesting to note that both groups showed an almost equivalent increase on each of the team skills. The highest increase in scores was observed for decision making skills (Group IBT: 64%, Group CBT: 50.1%), followed by interpersonal relationships (Group IBT: 19.1%, Group CBT: 16.4%) and an equal increase in scores for communication (Group IBT: 11.3%, Group CBT: 12%) and leadership (Group IBT: 11.3%, Group CBT: 12%).

Traditionally, team training has been delivered in a classroom environment by role playing, games, simulations, etc. [1] (Johnson and Johnson, 1994). Thus, the conventional approach has been highly interactive wherein the trainees and trainers interact at different levels throughout the training process. The fact that the CBT (specifically, the AMTT software) was able to achieve the same scores as IBT (an equally well developed classroom team training program) bodes well for the role of computers in imparting team skills knowledge. In other words, given equivalent content of the team training program, a well designed interactive computer-based team training program can be as effective as the traditional instructor-based team training program.

5.2. General usability

The development of the AMTT software followed an iterative design process to ensure that problems with the software design were identified and corrected before implementation. The cycle of design, test, measure and redesign was repeated a number of times in the development process (e.g. Ref. [12]). The user interface capitalized on the following: graphical user interface technologies, human factors research (i.e. color, formatting, layout, etc.), ease of use and information utilization (Helander, 1990; [4]; Eberts, 1994). Thus the AMTT software was developed after understanding the needs of the AMT, discussions with experts from Lockheed Martin and Greenville Technical College, following a process of iterative design and development and eventually resorting to detailed user testing (with instructors, supervisors and AMTs). The usability and knowledge test scores clearly indicate that the resulting product was well received by the users and helped increase their knowledge on the teamwork skills. Figure 4 shows the results of the general usability questionnaire with mean scores for the four separate usability issues: (1) content, (2) mechanics, (3) format and (4) usefulness. For each usability issue, there was no significant difference in the satisfaction between the groups. Also, when the four usability issues were consolidated (combined average score), there was no significant difference between the groups. These results were encouraging as they indicated that users were equally satisfied with either a highly interactive computer environment or a traditional classroom environment. Chandler [5], found similar results using a media rich computer software (System Training for Aviation Regulations — STAR) to teach Federal Aviation Regulations (FARs) to A&P students. In that study, the students showed a high degree of satisfaction with interactive stories and true-to-life situations presented through CBT.

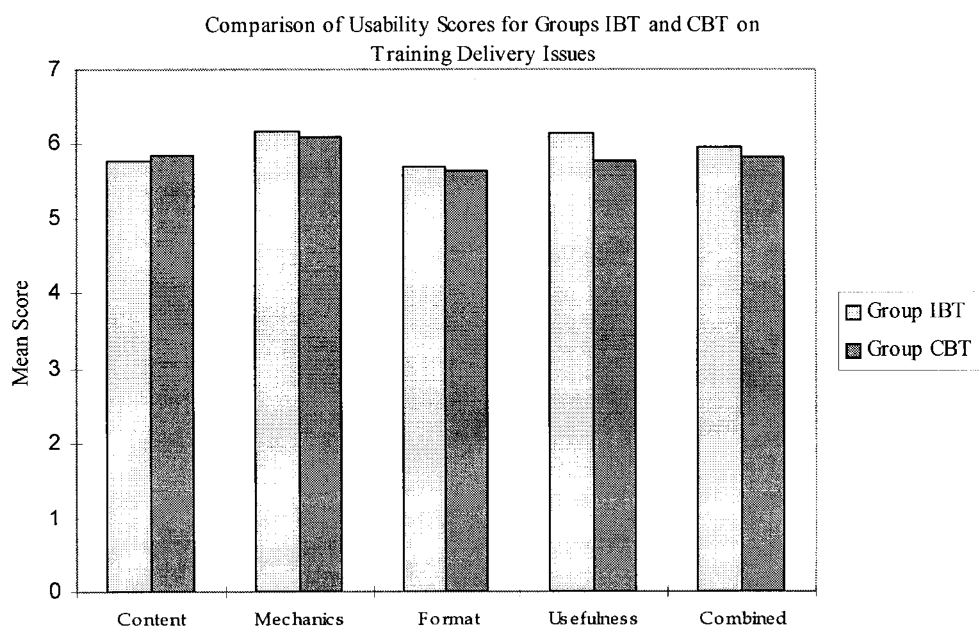

Fig. 4. Comparison of usability scores for groups IBT and CBT on training delivery issues.

Comparable satisfaction levels between users of hypermedia- and paper-based training have also been noted by Ivaturi et al. [15].

5.3. Training specific usability

For each usability category (presentation and format), the IBT subjects rated the usability significantly higher than the expected average of 3.5. The question with the highest score was F3 (The instructor interacted well with the students). This high score may have been due to the fact that the subjects may have viewed all aspects of the instructor and not just the instructors performance during training (e.g. casual conversations with subjects prior to and after training). The lowest score was for question F2 (The overhead projections were easy to see).

The scores on the usability specific portions (i.e. presentation and format) for Group CBT were similar to those achieved by Group IBT. Group CBT also provided high ratings to the AMTT software on various delivery system specific issues. One of the lowest scores (4.67) was assigned to question F3 "The delays while the computer worked did not frustrate you". Although training was conducted using state of the art Pentium multimedia machines (8 MB RAM), the computer program often slowed down as the program progressed through the different modules. This was most evident when videos and complex images were loaded toward the end of training. As training progressed, the computer had to keep track of several different variables which had to be constantly updated, also the software required more computer memory and competed with other parallel tasks for additional memory. This evidently slowed the presentation of material which could have attributed to the subjects' feelings of frustration with the AMTT software. In the future, as more powerful computers become available, the problem will be resolved.

A high score (6.22) was given to question P2 (The tutorial was easy to use). This response was encouraging since it was observed that several of the subjects receiving CBT had never used a computer before. In these cases, subjects were initially introduced to some basic computer operations (e.g. training on how to hold a mouse, training on how to use a mouse, training on how to navigate using the mouse and buttons). Once into the program, the less computer literate subjects were able to complete the four team skills modules without any assistance.

Thus, the high usability scores on the general and delivery specific portions of the usability questionnaire shows subjects' overall satisfaction with both the training programs. Furthermore, both the training programs were comparable on similar usability measures. Moreover, the significant improvement in posttraining team skills knowledge indicates that both training systems were equally effective in improving subjects' knowledge on team skills. In conclusion, we can state that IBT and CBT were closely similar based on: (1) subject's posttraining team skills perception scores, (2) posttraining team skills knowledge and (3) subjective satisfaction on usability issues.

6. Application of the AMTT software

Although designed primarily for research on team training in the aircraft maintenance environment, the AMTT software is envisioned to become a permanent part of the training program for aircraft maintenance technicians in a variety of organizations such as fixed based operations (FBOs), airlines, repair stations and overhaul facilities. Due to the flexible nature of computer-based training, individual AMTs may be pulled from their work as time permits to receive training in teamwork skills either as recurrent training or remedial training (refer to Fig. 5). At the completion of the team training course, an AMT may, at the discretion of the employer, receive a certificate of completion.

The supervisor or crew lead will continue to monitor the effectiveness of their crew(s) in performing those activities and tasks requiring team skills. In the event of an incident or accident, management will examine the root cause. If it is determined that a lack of a particular teamwork skill precipitated the event, then those individuals involved may be required to retake all or part of the CBT on team skills. Management may also evaluate previous test scores that are maintained in the instructors module.

The AMTT software can also be used for recurrent training of AMTs. Recurrent training has been proven to be an effective training intervention to maintain a level of proficiency. It has been suggested that recurrent training would be effective in providing teamwork skills in the aviation maintenance environment [9]. Thus the AMTT software may be used as a first introduction of teamwork skills to the AMT population with more advanced recurrent training provided at a later date, or as the follow-up training to a classroom delivery of team work skills.

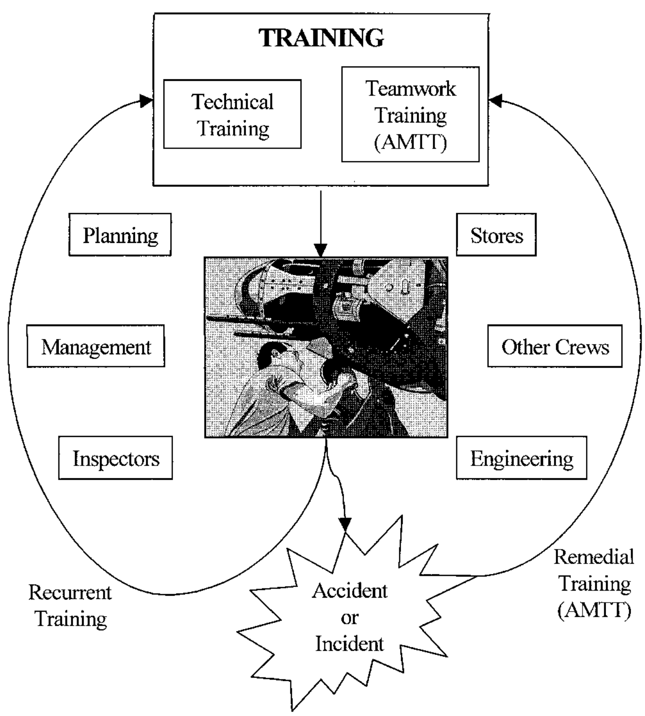

Fig. 5. Training cycle for the aircraft maintenance technician.

7. Conclusions

The goal of this research was to understand the role of team training and specifically that of advanced technology in the aircraft maintenance environment. As part of the research, a computer-based team training software — Aircraft Maintenance Team Training (AMTT) software — was developed. In this study, usefulness of AMTT was tested against a traditional classroom method of instruction in terms of team knowledge acquisition and usability issues. The important conclusions are summarized below.

1. Team training enhanced the knowledge of individuals on team skills. However, the type of training delivery system did not have a significant effect on the individual's ability to acquire team-skills knowledge.
2. There were no significant differences between IBT and CBT in terms of user satisfaction. Both the training delivery systems reported a high level of user satisfaction on the general and delivery specific portions of the usability questionnaire. Analysis of the general usability questionnaire on specific issues such as content, mechanics, format and usefulness did not reveal any significant differences between the two training delivery systems. It was encouraging to find that subjects with low levels of computer literacy were able to interact and use the AMTT software after minimal instructions on basic computer operations.
3. Many times CBTs fail because software designers fail to design interfaces and systems that users can understand. A user-centered design approach is required with an iterative process of design, test, measure, modify and retest. This procedure was used in the development of the AMTT software and a user friendly product was produced. In this study, there were subjects who were not computer literate, yet they were able to interact with the AMTT software without assistance. Although these subjects did not have any previous computer experience to help direct their actions, they completed the tests and questionnaires, advanced systematically through the modules, replayed both the audio and videos and gained knowledge from the training. This demonstrated the effectiveness of the iterative development methodology employed in this study.
4. After analyzing the results of both the CBT and IBT teams, the results are unequivocal. CBT (i.e. AMTT) was as effective in delivering team training instruction as IBT. Finally, the iterative design methodology employed in this study proved to be useful in designing an effective computer-based team training software. The above results have obvious ramifications for the use of AMTT for team training in the aircraft maintenance environment. In addition to being as effective as existing instructor-based team training methodologies, use of AMTT for team training has other obvious advantages:
   - Standardization: AMTT provides a systematic and consistent curriculum. Aircraft maintenance instructors at various facilities use their own unique training strategies (lectures, classroom discussions, video examples, etc.). In addition, some maintenance instructors who are technically competent may not have sufficient team skills knowledge to train AMTs on teamwork. The AMTT software provides a standardized and systematic team skills training program which aircraft maintenance instructors (at certified repair stations, airline companies, general aviation stations and A&P schools) can use to provide team skills training.

- Adaptability: traditionally, maintenance training has been accomplished via on-the-job training or classroom training, both of which are manpower intensive. It requires careful scheduling of personnel or encumbers others in the training process. AMTT is adaptive, self-paced and can be done at convenient times when trainees are available and need only involve the person being trained.
- Record keeping: the record keeping capabilities of AMTT tracks the student's progress. This information can be used by the instructor/supervisor to design remedial training.
- Cost effectiveness: team training using AMTT can be cost effective because: (1) it can be delivered on-site thus eliminating travel expenses for the trainer and the trainee and (2) it can minimize down-time by providing training at times that are convenient to the trainee and the company's work schedule. In larger organizations, AMTT can be delivered to many people at multiple sites thereby proving to be cost effective.
- Use of advance technology: many facilities (e.g. A&P schools and fixed based general aviation facilities) do not have access to larger aircraft. The AMTT software provides team skills training against the backdrop of maintaining a DC-9. The trainees not only acquire knowledge and skills on teamwork, but also gain an understanding of the importance of teamwork in the maintenance of wide-bodied aircraft.

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